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Effect of Drip Fertigation on Growth, Yield and Quality of Ratoon Sugarcane

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted at Zonal Agricultural Research Station, V.C. Farm, Mandya, Karnataka, India during Kharif 2020-21. The effect of water-soluble fertilizers on performance of ratoon sugarcane *(Saccharum officinarum)* as influenced by fertigation through surface drip irrigation was studied. The soil at the experimental site was red sandy loam with neutral pH (6.7), normal electrical conductivity (0.21dS m^{-1}), medium organic carbon (5.2 g kg^{-1}), low available nitrogen (275 kg ha^{-1}), medium phosphorus (35 kg ha^{-1}) and potassium content (280 kg ha^{-1}). The experiment was laid out in Randomized Complete Block Design with three replications comprising seven treatments using VCF-0517 sugarcane mild late (12-14 months) maturing variety. The application of WSF at 125 per cent RDF (312.5:125:156:N:P_2O_5:K_2O) through drip fertigation showed significantly superior growth and yield attributes viz., plant height (357.0 cm), no. of tillers

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clump^{-1} (15.0), internode length (16.67 cm), cane dry weight (54.8 t ha^{-1}), millable canes (8.17 clump^{-1}), cane length (341.67 cm), cane girth (3.30 cm), single cane weight (2.40 kg), number of internodes cane^{-1} (21.40) and cane yield (182.67 t ha^{-1}). Also, superior juice qualities such as juice extraction percentage (70) and sugar yield (20.88 t ha^{-1}) were recorded. The results clearly indicated application of water-soluble fertilizers at 125 per cent RDF through surface drip fertigation resulted in higher growth and yield of sugarcane due to enhanced water and nutrient use efficiency.

Keywords: Fertigation; sugarcane; drip fertigation.

1. INTRODUCTION

Sugarcane (*Saccharumofficinarum* L.) is remunerative commercial crop. Globally, cultivated for the production of sugar, fibre, bio-fuel and manure besides many by-products. The crop is grown primarily for sugar, gur and khandasari production. Due to growing population, demand for sweeteners is ever increasing; hence further emphasis is required to increase production and productivity. The horizontal expansion of the area under the sugarcane crop in all probability is not possible due to stiff competition from food, fibre and oil seed crops, besides urbanization and industrialization with growing population. Apart from land, scarcity of water & labour, high input cost, scarcity of irrigation water is directing us to increase water productivity. Its effective management is most critical, not only reducing wasteful usage, but also reducing production costs and sustaining productivity [1]. Innovative technologies namely drip fertigation with water soluble fertilizers will have to be adopted at farm level for enhancing production and productivity of sugarcane with higher resource use efficiency.

The improved irrigation water management with nutrient application is essential not only for increasing yield, but also lowering the cost of cultivation of sugarcane. Fertigation enhances yield of sugarcane by synchronizing nutrient supply as per crop demand besides saving fertilizer to an extent of 25-30 per cent [2]. Fertigation minimizes leaching of water and nutrients from the rhizosphere, thus minimizes groundwater contamination. Through irrigation system, soluble fertilizers are transported directly to the feeding zone by frequent application in smaller quantities. This provides valuable alternative opportunities for growing crops under conditions close to those of nutrient solution, when properly handled. The higher installation cost of the drip irrigation system is a major deterrent in adopting the drip system on field scale. However, the cost could be reduced by altering planting geometry (Paired row system). Though fertigation related research in sugarcane is not limited, identification of location specific optimum levels of fertilizers in sugarcane under drip fertigation to enhance productivity and studying the impact of application of MAP (Mono Ammonium Phosphate) which is an acidic fertilizer requires prime attention. Such information is meagre particularly in the soils of southern dry zone of Karnataka. Keeping this in view the present study was conducted.

2. MATERIALS AND METHODS

The field experiment was conducted at Zonal Agricultural Research Station, V.C. Farm, Mandya, Karnataka, India. The station is situated between 12°18’ and 13°04’ North latitude and 76°19’ and 77°20’ East longitude and at an altitude of 697 meters above mean sea level in southern dry zone (Zone–VI of NARP) of Karnataka which falls in southern dry zone (Region III) of India. The soil belongs to the *Alfisols* as per USDA classification.

The experiment was laid out in Randomized Complete Block Design with three replications comprising seven treatments viz., absolute control (T_1), Soil based application of 250: 100: 125 kg of N, P_2O_5, K_2O ha^{-1}with Urea, SSP and MOP conventional fertilizers @ 100 per cent RDF(T_2), Soil based application of 100 per cent RDF with farm yard manure(T_3), four fertigation levels with Urea, MAP and MOP water soluble fertilizers (150, 125 , 100 and 75 % of RDF, T_4-T_7) supplied through venturi during drip irrigation using VCF-0517 sugarcane mid late (12-14 months) maturing variety as test crop in plant and ratoon crops.

The recommended FYM (15 t ha^{-1}) was applied uniformly to all the treatments except for T_1 and T_2 treatment plots. The conventional fertilizers were applied as per recommended dose of fertilizer (250: 100: 125 kg of N, P_2O_5, K_2O ha^{-1}), 30 per cent N, 100 per cent of P & K were applied with Urea, SSP and MOP at 30 days after harvesting of main crop and remaining 70 per cent of N was applied with two equal splits at 60 and 90 days after harvesting of main crop using Urea, while for drip fertigation plots N, P and K were applied as per nutrient scheduling (Appendix 1) using Urea, MAP and MOP. The irrigation was provided using ground water through bore well (1.2 kg cm-2 water yield) through drip irrigation considering climatic conditions and crop demand, while fertigation was provided twice a week.

Composite soil samples were drawn from the experimental site during the growth stages and samples were air dried, powdered, sieved and analysed for various physical and chemical properties. Data recorded on various observations *viz.*, growth, yield, quality and soil parameters generated from treatments imposed were subjected to analysis of variance as per the procedures outlined by Rangaswamy [3]. The level of significance used in 'F' and 't' tests were at $p \leq 0.05$ and critical difference values were calculated wherever the 'F' test was found to be significant.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

The higher growth parameters were recorded in drip fertigated treatments as compared to conventional soil based fertilizer application. Among the fertilizer levels response was observed up to 125 per cent RDF, further @ 150 per cent RDF slight decrease in growth parameters was observed. The observations on various growth parameters of ratoon sugarcane such as plant height (cm), number of tillers (clump^{-1}), internodal length (cm) and cane dry weight (t ha^{-1}) at the time of harvesting are furnished in Table 1. Application of 125 per cent RDF through WSF recorded significantly higher plant height (357.0 cm) compared to 75 per cent RDF through WSF (325.0 cm). Soil application of 100 per cent RDF through conventional fertilizer with FYM (314.0 cm) and without FYM (304.7 cm) were significantly lower than fertigation treatments. The plant height increased with increased levels of drip fertigation might be due to continuous accessibility to nutrients and moisture within the rhizosphere and also due to increased root proliferation with better utilization of nutrients. The better availability of nutrients at critical stages of crop growth resulted in greater plant height which helps for cell division, differentiation and cell metabolism in successive stages. The similar observations were noticed by Gul et al. [4] in Maize.

Cane yield mainly depends on the number of millable canes and hence tillering is the principal component attributed towards achieving higher cane yield. Therefore, the number of tillers clump^{-1} with the application of 125 per cent RDF through WSF was significantly higher (15.0 clump^{-1}) compared to 75 per cent RDF through WSF (11.0 clump^{-1}).Soil application of 100 per cent RDF through conventional fertilizer with FYM (9.33 clump^{-1}) and without FYM (8.0clump^{-1}) showed significantly lower number of tillers per clump compared to WSF applied treatments. Generally, tillering was higher in all the drip fertigation treatments compared to soil application of conventional fertilizers. Due to wider row spacing facilitates optimum sun light and proper aeration resulted in production of more number of tillers with higher cane girth and weight by utilizing supplemented nutrients to the root zone through water soluble fertilizers administered through drip irrigation as presented in Table 2 at very frequent interval up to 9th month of crop growth.

The application of water-soluble fertilizers (Urea, MAP and MOP) supplied the nutrients during the critical crop growth stages synchronizing with the demand and reaching nutrient absorbing sites as compared to soil application of urea, SSP and MOP. Early vigorous growth of cane with the availability of required quantity of water and nutrients at the early stages with WSF compared to soil application of fertilizers where in the fluctuation in nutrient availability is very wide [5]. Favourable moisture availability under drip fertigation enhanced nutrient uptake and favoured for good tiller production as indicated by Chaudhary [6] and Parthasarathi et al., [7].

Drip fertigation with different levels at harvest recorded significantly higher internodal length in T_5 (16.67cm) compared to T_7 (13.0 cm). Whereas significantly lower internodal length was recorded in soil application of conventional fertilizer with FYM (11.50 cm) and without FYM (10.20 cm) compared to fertigation treatments. The supply of 125 per cent RDF through WSF resulted in thick and longer internodes which can be attributed to timely supply of adequate nutrients and moisture leading to greater photosynthetic activity and transportation of photosynthates [8].

Table 1. Growth attributes of sugarcane as influenced by levels of water-soluble fertilizers through drip fertigation

Treatments	Growth parameters			
	Plant height (cm)	Number of tillers (per clump)	Internodal length (cm)	Cane dry weight (t ha^{-1})
T_1	286.7	6.00	8.70	27.8
T_2	304.7	8.00	10.20	42.0
T_3	314.0	9.33	11.50	44.2
T_4	354.0	14.67	16.00	54.0
T_5	357.0	15.00	16.67	54.8
T_6	341.7	13.00	14.50	50.5
T_7	325.0	11.00	13.00	47.3
S.Em ±	3.4	0.45	0.48	1.02
CD ($p \leq 0.05$)	10.4	1.39	1.48	3.06

Note: RDF: Recommended Dosage of Fertilizer- 250:100:125 kg NPK ha^{-1}, FYM: Farm Yard Manure, Urea, SSP and MOP applied to soil in T_2 and T_3; Urea, MAP and MOP applied through drip T_4 to T_7

Table 2. Nutrient scheduling for sugarcane for fertigation

Crop growth stages	N (%)	P_2O_5 (%)	K_2O (%)
0 to 60 days	32	25	25
61 to180 days	58	75	25
181 to 270 days	10	0	50

Note: The N, P_2O_5 and K_2O were supplied through Urea, MAP and MOP

Drip fertigation with different levels at harvest recorded significantly higher cane dry weight at 125 per cent RDF (54.8 t ha^{-1}) compared to 75 per cent RDF (47.3 t ha^{-1}). Whereas significantly lower cane dry weight was recorded in conventional fertilizer soil-based application with FYM (44.2 t ha^{-1}) and without FYM (42.0 t ha^{-1}) compared to fertigation treatments. Higher cane dry weight noticed in drip fertigated treatments might be due to greater nutrient uptake because of continuous and uninterrupted nutrient and moisture supply, which full filled the crop demand. This must have led to increased plant metabolic activity resulting in higher accumulation of dry matter. These findings are in line with Tiwari et al. [9].

Significant influence of different levels of water-soluble fertilizers through drip fertigation on yield determining components such as single cane weight, cane length, cane girth, number of millable cane, number of internodes per cane and cane yield are presented in Table 3. Significantly lower single cane weight was recorded in basal application of conventional fertilizer with FYM (1.35 kg) and without FYM (1.32 kg) compared to WSF applied treatments like T_4, T_5, T_6, T_7.

The increased cane weight under drip fertigation could be due to better availability of nutrients and soil moisture at the rhizosphere to meet the crop demand with optimum sunlight and better aeration under paired row system of planting. The increased cane length, girth and number of internodes per cane might led to increased single cane weight and advantageous influence was due to greater uptake of nutrients, thereby improving cell division and cell elongation, which eventually resulted in higher cane weight [10].

3.2 Yield Parameters

Cane length at harvest with the application of 125 per cent RDF through WSF was significantly higher (341.67 cm) compared to 75 per cent RDF through WSF (278.33 cm). Soil application of 100 per cent RDF through conventional fertilizers with FYM (240.67 cm) and without FYM (228.33 cm) recorded significantly lower cane length than WSF applied treatments. Drip fertigation with WSF applied treatments recorded higher cane length, which might be because of greater availability of nutrients and soil moisture in the rhizosphere area, which might cause higher root proliferation and higher nutrient uptake. The results of this investigation are similar to the findings of Dilip and Mandakini (2015). Cane girth of ratoon sugarcane at harvest was found to be significantly higher in 125 per cent RDF through WSF (3.30 cm) compared to75 per cent RDF through WSF (2.50 cm). Drip fertigation treatments recorded significantly higher cane girth compared to conventional fertilizers based soil application with FYM (2.10 cm) and without FYM (1.98 cm).

Higher cane girth in WSF applied treatments compared to conventional soil-based applications was mainly due to better availability of water and nutrients that might help in achieving higher photosynthetic rate, resulting in higher yield parameters.

Application of WSF at 125 per cent RDF through drip fertigation recorded significantly higher number of millable canes at harvest (8.17 clump^{-1}) compared to 75 per cent RDF through WSF (7.0 clump^{-1}). Soil application of 100 per cent RDF through conventional fertilizers with FYM (6.55 clump^{-1}) and without FYM (6.43 clump^{-1}) recorded significantly lower millable cane than WSF applied treatments. This increased number of millable cane was also due to better and early conversion of tillers into millable canes. Otherwise, this would have resulted in the excess production of tillers in the early stages and would have diverted plant nutrients unnecessarily for unproductive purpose. These results are in accordance with the findings of Ghugare and Lokesh [11].

Drip fertigation with different levels of WSF at harvest recorded significantly higher number of internodes per cane with 125 per cent RDF (21.40) compared to 75 per cent RDF (17.43). Whereas, significantly lower number of internodes per cane was recorded in basal application of conventional fertilizer with FYM (15.70) and without FYM (15.60) compared to WSF applied treatments. Thick and longer internodes noticed with WSF might be due to continuous supply of water and nutrients resulting in higher photosynthetic ability leading to greater number of internodes per cane [12]. The rapid multiplication of cell, cell division and elongation results in greater number of internodes per cane [13].

Soil application of 100 per cent RDF through conventional fertilizers with FYM (146.75 t ha^{-1}) and without FYM (139.33 t ha^{-1}) recorded significantly lower cane yield compared to WSF applied treatments. A greater yield of cane in drip fertigated treatments might be due to higher plant height, number of tillers, internodal length and cane girth. This couldhave resulted in higher production and accumulation of dry matter, higher photosynthetic activity resulting in improved yield and yield parameters. These observations are in conformity with the findings of Prabhakar et al., [14].

3.3 Quality Parameters

The juice quality parameters such as juice extraction percentage, brix per cent, pol per cent, purity per cent and commercial cane sugar per cent and sugar yield were presented in Table 4. Soil application of 100 per cent RDF through conventional fertilizers with FYM (51.11 %) and without FYM (48.73 %) were recorded significantly lower juice extraction per cent than fertigation treatments.

Effect of different levels of water-soluble fertilizers through drip fertigation and conventional fertilizer application did not influence significantly quality parameters like brix, pol, purity and CCS per cent. Sugar yield is the product of commercial cane sugar and cane yield and differed significantly among the treatments. The enhanced sugar yield with WSF might be mainly due to improved juice attributes such as brix, pol percent, purity per cent and CCS per cent as a result of consistent millable cane production under drip fertigation treatments. The increased sugar yield is observed under drip fertigation with the use of WSF by Mahesh et al., [15].

3.4 Effect on Soil Properties

Application of nutrients through WSF at varied levels had no significant changes with respect to soil parameters viz. P^H, EC and organic carbon contents (Table 5). The soil reaction (pH) is slightly acidic to neutral, electrical conductivity is normal and Organic carbon is medium in status. Whereas primary nutrients contents in soil after harvest were significantly increased in the treatment applied with WSF at 150 % RDF. The higher nitrogen, phosphorus and potassium content in the soil was noticed upon addition of higher dose as fertilizer may results in higher availability of nutrient in the soil [5].

3.5 Effect on Water Use Efficiency and Benefit Cost Ratio: (Fig. 1)

Fertigation with varied levels of RDF through WSF had no significant effect on water use efficiency. Application of 125 per cent RDF through WSF (1.08 t ha^{-1} cm^{-1}) found statistically on par with 150 per cent RDF (1.06 t ha^{-1} cm^{-1}) and 100 per cent RDF (0.99 t ha^{-1} cm^{-1}).

However, due to lower cane yield, the least WUE was noticed with control (0.54 t ha^{-1} cm^{-1}). The effective utilization of available water supplied at regular intervals throughout the crop period based on crop demand increases the water productivity under drip fertigation system.

Table 3. Yield and yield parameters of ratoon sugarcane as influenced by levels of water-soluble fertilizers through drip fertigation

Treatments	Single Cane weight (kg)	Cane length (cm)	Cane girth (cm)	No. of millable canes $clump^{-1}$	No. of internodes $Cane^{-1}$	Cane yield (t ha^{-1})
T_1	1.00	201.00	1.62	5.83	13.90	92.37
T_2	1.32	228.33	1.98	6.43	15.60	139.33
T_3	1.35	240.67	2.10	6.55	15.70	146.75
T_4	2.35	333.00	3.24	8.00	20.97	179.92
T_5	2.40	341.67	3.30	8.17	21.40	182.67
T_6	2.00	310.33	2.90	7.60	19.20	168.25
T_7	1.67	278.33	2.50	7.00	17.43	157.67
S.Em ±	0.10	6.57	0.10	0.11	0.52	3.35
CD (p≤0.05)	0.31	20.25	0.32	0.34	1.59	10.33

Note: RDF: Recommended Dosage of Fertilizer- 250:100:125 kg NPK ha^{-1}, FYM: Farm Yard Manure, Urea, SSP and MOP applied to soil in T_2 and T_3; Urea, MAP and MOP applied through drip in T_4 to T_7

Table 4. Quality parameters of sugarcane juice as influenced by levels of water-soluble fertilizers through drip fertigation

Treatments	Juice extraction (%)	Brix (%)	Pol (%)	Purity (%)	CCS (%)	Sugar yield (t ha^{-1})
T_1	42.14	19.03	15.97	83.85	10.76	9.89
T_2	48.73	19.73	16.56	83.97	11.16	15.55
T_3	51.11	18.57	16.50	89.13	11.44	16.79
T_4	67.55	19.00	16.56	87.18	11.38	20.52
T_5	70.02	19.27	17.03	88.95	11.44	20.88
T_6	62.03	18.60	17.50	90.27	11.73	19.72
T_7	56.65	18.50	16.8	88.09	11.25	17.74
S.Em ±	1.30	0.26	0.13	2.63	0.49	0.50
CD (p≤0.05)	4.00	NS	NS	NS	NS	1.52

Note: RDF: Recommended Dosage of Fertilizer- 250:100:125 kg NPK ha^{-1}, FYM: Farm Yard Manure, CCS: Commercial cane sugar, Urea, SSP and MOP applied to soil in T_2 and T_3; Urea, MAP and MOP applied through drip in T_4 to T_7

Table 5. Physico-chemical properties of soil as influenced by levels of water-soluble fertilizers through drip fertigation

Treatments	pH	Electrical Conductivity dSm^{-1}(1:2.5)	Organic Carbon g kg^{-1}	Available N	Available P_2O_5	Available K_2O
				Kg ha^{-1}		
T1	7.05	0.26	4.91	102.50	12.70	103.93
T2	6.70	0.25	4.75	230.50	20.00	192.80
T3	6.64	0.26	5.24	238.90	22.00	200.50
T4	6.35	0.35	5.86	287.80	35.50	226.30
T5	6.39	0.34	5.78	220.50	32.00	218.60
T6	6.49	0.31	5.30	170.40	28.90	206.72
T7	6.67	0.29	5.14	103.00	25.80	201.80
S.Em±	0.15	0.04	0.64	11.36	1.00	8.00
CD	NS	NS	NS	34.99	3.08	24.66

Note: RDF: Recommended Dosage of Fertilizer- 250:100:125 kg NPK ha^{-1}, FYM: Farmyard Manure, Urea, SSP and MOP applied to soil in T_2 and T_3; Urea, MAP and MOP applied through drip T_4 toT_7 treatments

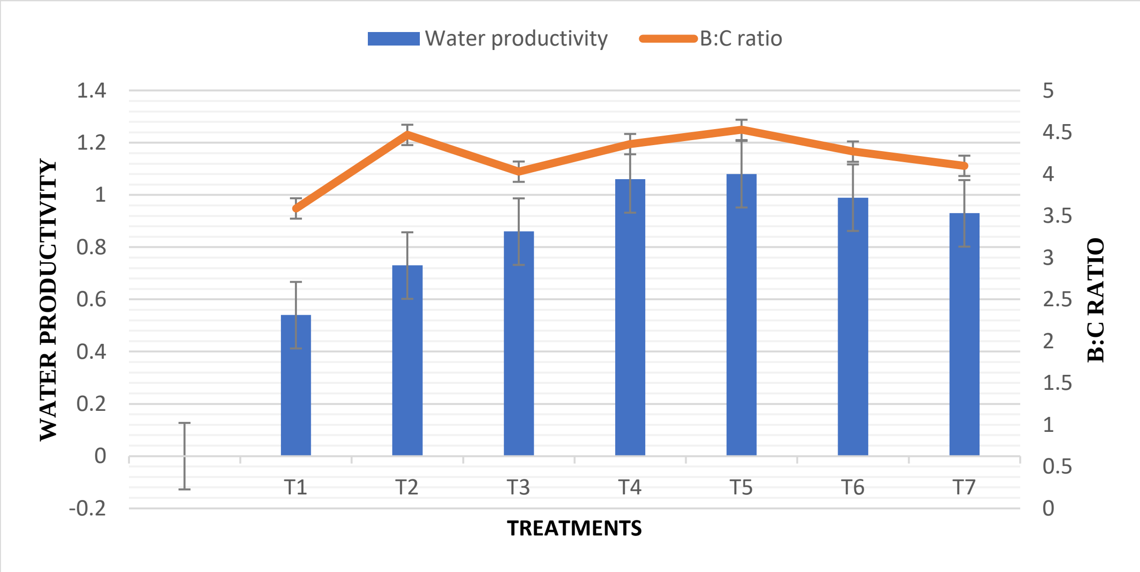

Fig. 1. Effect of drip fertigation on water productivity and B:C ratio

The benefit cost ratio was noticed to be higher under water soluble fertilizers applied treatments compared to conventional soil based fertilizers. The capital investment on drip irrigation system has been compensated by sugarcane crop as one of the perennial commercial crops. The adoption of altering planting geometry i.e., paired row planting with wider spacing facilitated mechanization, supplying water through drip based on crop demand to the root zone minimizes weed growth, enhanced water and nutrient use efficiency and also considering self-life period of drip irrigation system the benefit accrued out of drip irrigation will be for longer period [16-18].

4. CONCLUSION

The higher growth and yield of sugarcane was recorded in drip fertigated treatments as compared to conventional soil based fertilizer application. Based on the results, inferred that application of varied levels of WSF through drip fertigation showed significantly higher growth, yield and quality attributes compared conventional soil based fertilizer application. Application of WSF at 125 per cent RDF through drip fertigation for sustaining yield and higher economic returns.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Appendix 1. Fertigation scheduling for Sugarcane (RDF- 250: 100: 125 kg of N, P_2O_5 and K_2O ha^{-1})

Crop growth stages (Days)	Nitrogen (Kg)	Urea 4 days once (kg)	Phosphorus (Kg)	MAP (12:61:0) 4 days once (kg)	Potash (Kg)	MOP 4 days once (kg)
0-30	25	3.7	12.5	2.7	7	1.7
31-60	30	8.0	12.5	2.7	9	2.0
61-90	35	8.8	25.0	5.4	12	2.6
91-120	40	10.2	25.0	5.4	15	3.3
121-180	50	6.6	25.0	5.4	42	4.6
181-220	50	5.4	-	-	35	5.8
221-270	20	3.4	-	-	5	0.7
Total	**250**	**-**	**100**	**-**	**125**	**-**

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